

SCIENCE FOR GLASS PRODUCTION

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PROCESSES OF GLASS PRODUCTION AND MOLDING ON A MULTI-PURPOSE PRODUCTION LINE

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A theoretical substantiation of combining the technological processes for producing a glass band of varying thickness, size, texture, and surface-layer composition is provided and the results of its practical implementation are discussed.

The majority of existing float-glass lines produce a narrow range of glass. A result of this specialization is an extended network of companies recycling sheet glass. At the same time, most decorative and functional coatings can be produced simultaneously with molding glass in a melt tank, since the glass melt spreading and molding in the form of a glass band serves as a hot substrate for the processes of physicochemical modification of glass by various reactants.

The main advantage of float production of sheet glass is universally known, i.e., ensuring a high degree of polish of the glass surface by molding it on top of molten metal [1 – 4]. The particulars of this processes are as follows.

The glass melt from the horizontal layers of the working flow is transported in the form of a laminar stream onto the surface of molten tin with a minimum fraction coefficient, which allows for the glass melt to spread freely until it reaches an equilibrium thickness. The glass melt at the temperatures of discharge, spreading, active molding, and solidification of the glass band exists in an active chemical and physical state, which determines its reactions with gaseous, liquid, and solid reactants, as well as their mechanical effect on the glass. Since the duration of the glass staying inside the melt tank ranges from a few minutes to tens of minutes in a controlled atmosphere, and the temperature of tin in the tank varies from 1000 to 600°C, these conditions are sufficient for glass treatment by modifying the composition, output, width, and thickness of the glass band.

Considering the fact that the processes of glass-band treatment take place in specific temperature-viscosity conditions, the purpose of our study was to determine the extent of the active molding zones for glass of varying thickness and the technological thermal zones along the melting tank, in

which treatment and modification of the glass band is implemented in producing various types of glass.

The main object of the study was the experimental production line of the Saratov Institute of Glass with an output of 100 tons/day, which was considered a hot prototype of a multifunctional production line.

A long-term period of research (from 1969 up to the present) led to the possibility of a large-scale study of the regularities of the processes of melting clear and tinted glass melt and molding glass bands of varying thickness, size, and surface texture.

The research methods on the experimental production line of the Saratov Institute of Glass have their specifics. Apart from the standard continuous monitoring of glass melting and molding (over 200 control points), as well as the monitoring of the quality parameters of raw materials, the batch, the glass melt, and the finished glass, various traditional and specific methods were used for controlling the temperature, spectral characteristics, density, and homogeneity of the glass, such as striascopy, schlieren photography and viscosimetry, differential-thermal analysis, electron microscopy, chemical pickling of glass in layers, etc. The frequency of taking samples was selected to characterize the modifications of glass and modification dynamics.

Tags on the glass-band surface were used to determine the velocity of the band migration along the tank, and simultaneously the width of the glass band was measured in the most characteristic zones of the tank. The temperatures were measured using a specially developed method, which makes it possible to reveal the true temperature of the glass-band surface, as it migrates along the melt tank. The viscosity of glass within the interval from 10^4 to 10^{13} P (1 P = 0.1 Pa · sec) was measured on a universal viscometer [5].

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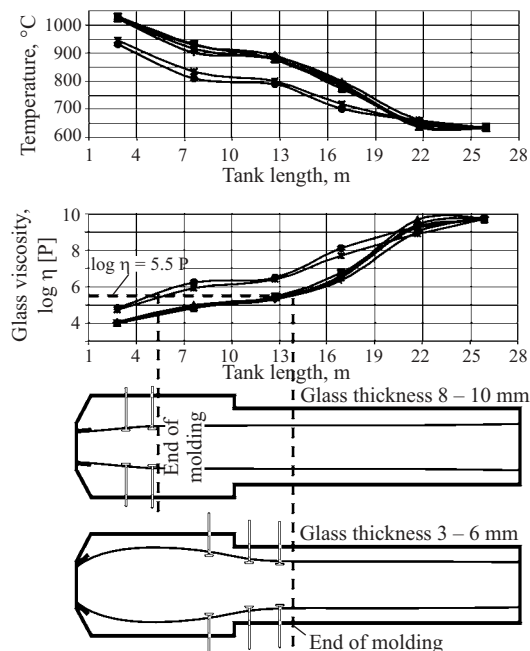


Fig. 1. Variations in the main molding parameters along the melting tank for glass of varying thickness.

Figure 1 shows the temperature and viscosity characteristics of glasses of various standard sizes. It was established that the rate of spreading is determined by the kinetics of a viscous flow and the variation (the rate of increase) of viscosity with a decreasing temperature. A uniform spreading occurs under the effect of gravity and surface tension forces, provided that the glass-melt viscosity is not more than $10^{3.5}$ P. Under these conditions, the spreading lasts 70 sec, i.e., it is sufficient to ensure a plane-parallel position of the band, and ends at a temperature of $1060 - 1020^{\circ}\text{C}$ [2]. The longitudinal and lateral stretching ends with the formation of a band of the required width and thickness having a viscosity of $10^{5.5}$ P.

The heat transfer at the temperatures of glass-melt spreading and molding mainly occurs as exchange of radiant energy; therefore, the characteristics of the glass absorption in the IR spectrum have a perceptible effect on the temperature gradient of different layers of the glass band.

The arising temperature difference between the middle and the surface layers and increasing viscosity of the surface layers produce the effect of a fast curing of glass, although its middle layers still preserve their fluidity. This interval is shorter in a heat-absorbing glass than in a clear glass (by $30 - 40^{\circ}\text{C}$ in the discharge and spreading zone and by $10 - 20^{\circ}\text{C}$ in the active molding zone). The tinted heat-absorbing glasses require shorter molding zones than clear glasses [6].

Along with these specific regularities, the general regularities were determined for the production of glass of a wide thickness range.

The main parameters for all processes of molding glass on melted metal include the thickness and the width of the

band, whose values are initially prescribed and then measured in the finished product, as well as the molding rate determined by a calculation based on the known glass-melt flow rate.

The molding rate is calculated from the formula

$$v = \frac{Q}{bd\rho},$$

where v is the velocity of the glass band, cm/sec; Q is the glass-melt flow rate, g/sec; d and b are the thickness and the width of the glass band, cm; and ρ is the glass density, g/cm^3 .

The main principle of molding glass of a thickness above the equilibrium value (6.5 mm) consists of restricting the spreading of the glass melt over a short segment of the spreading zone and subsequent fast cooling of the glass band until it solidifies. It has been established that the length of the melting tank need not be modified to produce glass of a more than equilibrium thickness. After the glass acquires a thickness of 8, 10, or 12 mm, it is possible to treat the viscoelastic glass band with a profiling roil and obtain the profiled Rhythm glass.

In producing thin glass of 3 – 6 mm thickness, an effective method is the longitudinal-lateral stretching of the glass band by a pair or several pairs of thinning machines. The active molding of thin glass ends at a temperature of $880 - 840^{\circ}\text{C}$ (viscosity $10^{5.5}$ P). Under these conditions, the contracting effect of surface tension already does not lead to a significant reverse narrowing of the band and thickening of the glass. The thinner the glass produced, the more extended is the active molding zone, which, in making glass 3 mm thick or thinner may reach up to 60% of the length of the melt tank.

It is demonstrated in Fig. 1 that the boundaries of the active glass-molding zones determine the required dimensions of the melt tank, in particular, its length, width, and the tin melt configuration.

During the evolution of the float-glass technology, the calculation methods and the standard sizes of the melt tank did not undergo substantial modifications. At the same time, hundreds of devices have been developed for the modification of the glass band inside the melt tank. All these years, the main field of research at the Saratov Institute of Glass has been modification of and imparting new functional properties to glass when developing new types of glasses and the technology of glass molding on a metal melt.

In developing processes for producing functional glasses adapted to the physicochemical conditions of the melt tank and suitable for inclusion into the standard molding technology, it was necessary to identify the most typical thermal zones along the melt tank (Fig. 2). Such processes as decoration (creating surface ruptures in producing the Metelitsa glass) and profiling (in producing the Rhythm glass) of the surface, electrochemical tinting, and deposition of a reflecting coating, as a rule, do not require additional extension of the tank (RF patent Nos. 2133714, 2144518, 2145308, 2145945, 2149837, 2147015, and 2174497). It should be noted that each specific method of glass treatment can take

up a substantial amount of space along the melt tank, but their integrated application within a single production cycle restricts these limits to optimum values.

Summarizing the results obtained makes it possible to implement a real complex of technologies on a multifunctional production line. Zone 1 is used to treat glass with a gaseous reactant to produce the Metelitsa (Snowstorm) large-relief glass or to deposit vitreous coatings (glass crumbs, filaments, etc.). In zone 2, it is possible to deform the glass band with a profiling roll and produce Rhythm glass of thickness 3–5 mm. Zone 3 is the most effective for the glass-band treatment with solid gas-forming reactants in producing the shallow-relief Metelitsa glass of 3–5 mm. Zone 4 is used to apply coatings using the electrochemical method, whereas silicon coatings are deposited in zone 5 by treating the glass band with silane or silane mixtures with other reactants.

Technologies have been developed which enable one to combine different techniques of glass-band treatment if the processes allow for their implementation in different zones along the tank. For instance, the Metelitsa deep-relief and shallow-relief glass and the Rhythm profiled glass can be decorated with electrochemical or silicon coatings, thus obtaining new products. It is also possible to combine several glass-treatment technologies within the same thermal zone. Thus, it is possible to combine the production of the deep-relief Metelitsa glass and its decoration with a vitreous coating in the same cycle and thus to obtain new varieties of the Metelitsa.

The principle of combining different glass-treatment methods in the same molding cycle made it necessary to upgrade the production technology of certain products, for instance the Metelitsa and the Rhythm glass.

It is recommended to produce the thin decorative Metelitsa brand by treating the glass band molded on melted metal with the products of volatilization of organosilicon compounds or wood pulp in the form of disperse particles weighing 0.05–0.20 g (RF patent No. 2133714). The volatilization proceeds in the nitrogen-hydrogen medium of the melt tank at a temperature of 850–900°C, and the volatilization products (gaseous compounds of carbon and silicon) react with the glass-band surface layer and form a chilled-on film. The film in the course of molding modifies the thermal fields on the glass-band surface, as a consequence of which fragmentary differences in thickness and surface ruptures arise due to the effect of the longitudinal-lateral stretching forces; in doing so, the exterior appearance and the thickness of the glass band are modified.

The Institute has developed several varieties of the Rhythm profiled glass (RF patent Nos. 2139834 and 2145581). A technology has been developed and over 500 thousand m² of this glass of bronze, pink, gray, and greenish-blue tints has been produced (a glass band of 4–12 mm). This is implemented as follows. The glass melt is discharged into a tank on top of the molten metal, and its flow acquires the shape of a plane-parallel band. The band is transported along the melt tank and is subjected to the effect of the profiling cylinder installed in the zone with a temperature not lower than 850°C and the pulling force of the con-

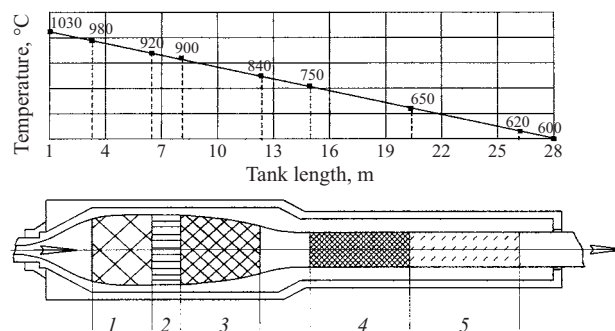


Fig. 2. The layout of the technological zones of glass-band treatment in a melt tank.

veyer belt of the annealing furnace. By combining the effect of the profiling roll and the pulling force of the annealing furnace conveyor, one can obtain a glass band with a prescribed thickness and a prescribed channeling profile. When producing the thin variety of the Rhythm glass (4–6 mm), the combined process includes two thinning stages that are interspersed by the profiling roll treatment of the glass band.

Thus, production technologies for the following glasses have been developed and implemented on a multifunctional production line of 100 tons/day capacity without modifying its design and the main production equipment:

- Metelitsa glass with a decorated surface;
- Rhythm glass with a profiled surface;
- glass with electrochemically tinted surface
- tinted heat-absorbing glass of various colors;
- glass with decorative vitreous coatings.

A wide range of technologies and equipment makes it possible to produce different varieties of glass at the same production facility and, therefore, to flexibly satisfy the regional demands in architectural, transport, furniture, and mirror glasses [7].

The developed glass-production technologies can be implemented on any existent float-glass lines.

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